Dynamic Handover Model for 5G Systems Based on Mathematical Weight Function

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Abstract__ In this paper, an Advanced Dynamic Handover Parameter Optimization algorithm based on a Weight Function (ADHPO-WF) is developed. This algorithm analytically estimates the Handover Control Parameters (HCPs) values individually as a function of User Equipment's (UE's) Signal-to-Interference-plus-Noise-Ratio (SINR), cells' load and UE's speed. The algorithm is validated over various mobility conditions in the 5th Generation system. The performance of the analytical HCPs estimation method is validated and compared with other handover algorithms from the literature, in term of Handover Probability (HOP), Handover Ping-Pong Probability (HPPP), and Radio Link Failure (RLF). The simulation results show that, the proposed ADHPO-WF is significantly outperformed the existing Handover Parameter Optimization (HPO) algorithms in various mobile speeds.

Keywords__*Handover parameter optimization; handover control parameters; LTE-Advanced Pro, and 5G Networks*

I. INTRODUCTION

Self-Optimization Network (SON) has been standardized as a fundamental feature in 4G and 5G systems . This technology has been started exactly from in the 3.9G systems, Long Term Evolution (LTE) (Release 9 (Rel.9)), and continuously developed further in 4G systems LTE-Advanced (Rel.10 to Rel.13) with Carrier Aggregation (CA) technique. In 5G systems, LTE-A Pro (3GPP Rel.14 to Rel.17) [1-3], the SON becomes more advanced technology and the developments are continuously going on. Whereas, From Rel.14 to Rel.17 will be the 3GPP 5G system for International Mobile Telecommunications 2020 (IMT-2020) standard. The main focus of SON is to keep up the system quality and execution with least manual mediation from the administrator [4]. In other words, SON in 5G system is mainly introduced to reduce the operating expenditure (OPEX) related with the controlling of this huge number of nodes from several vendor. Thus, it decreases the administrative need by network operators, as well as the complexity in network maintenance and management. The SON operation is defined as the process that automatically adjusted network parameters based on the measurements and performance of UE and evolved NodeB (eNB). In SON, there are several functions have been introduced to optimize the network parameters. Each function performs optimization to achieve different objectives.

The HPO, which is also known as Mobility Robustness Optimization (MRM) function, is one of the significant SON functions that have been introduced for 4G and 5G systems [1, 5-7]. The HPO aims to automatically adapt the HCPs values to solve the handover problems [8]. Apart from that, the handover is carried out when the UE is particularly moving in between the two cells in connected mode and this is intended for preserving the connection received by the UEs. The handover on a different note deals with the procedure [9], which influenced the UE's experience directly as it often occurred during the transmission of data packets by the UE. To be more accurate, the suboptimal settings of HCPs may consequently contribute to unnecessary handover, HPPP, or high RLF, which both will produce high redundancy due to wastage of network resource. Therefore, it is important to highlight the central objective of HPO algorithm, for reducing the number of HOP, HPPP and RLF that may be caused by the tuning of HCPs values.

Even though handover problems can be reduced by the utilization of conventional HPO (HPO-Cnv) introduced by 3GPP, it is still not considered as the best possible algorithm in HCPs optimization. Thus, the issue associated with the high HOP, HPPP and RLF need to be addressed and solution also needs to be attained. There are several algorithms concerning on optimizing the HCPs values and this can be referred in the literature. Different methodology have been used in these algorithms, and they were investigated in different environments. In [10], machine learning and data mining techniques were proposed to be used for optimizing handover parameters. It was investigated over LTE system in building environment. In [11], high mobility SON function was introduced to shorten the multi-layer time in LTE system. It performs the optimization by estimating the users' mobility behaviors based on measurements data collected previously by the users. In [12], an algorithm was introduced to adaptive adjust hysteresis margin based on the position of the user in the cell. Once the user getting closer to the cell edge the hysteresis margin is decreased more. In [13], enhanced mobility state estimation (EMSE) was introduced to optimize handover parameters (TTT and HM) based on the handover types and speed of users.

On top of that, it has also been proposed that Fuzzy Logic Controller (FLC) to be utilized in modifying the Handover Margin (HOM) level adaptively while a fixed value is set for the Time-To-Trigger (TTT) [14]. The HOM level is then adjusted by the FLC based on the two controls input parameters, known as DCP and Handover Ratio (HOR). Another method introduced as a gradient method and cost function-based mobility robustness optimization scheme been proposed for LTE femtocell [15]. It performs the optimization based on a cost function of various parameters.

The cost function calculated as a function of HPPP numbers, continuous handover, too early handover, too late handover, and handover to the wrong cell. Meanwhile, in [16], the HCPs values are tuned according to the average Handover Performance Indicator (HPI) by Weighted Performance based on Handover Parameter Optimization (WPHPO) algorithm. The WPHPO algorithm is evaluated as a function of Handover Failure Probability (HFP), HPPP and Drop Call Probability (DCP). According to [17] and [18], there are also other works which proposed a SON algorithm, but only one HCP is considered in their analysis, whereas, in [16] and [19], the techniques in modifying both the HOM and the TTT are proposed, but the further impact on UE speed is not investigated. In [20] and [21] the inter-system handover parameter optimization is taken into account for investigation. Lastly, the analysis on some performance of intra-frequency LTE handovers are explained in [22] and [23]. However, there are no SON algorithms provided in finding the best possible setting of HCPs values in the papers mentioned. Even though these algorithms contributed in enhancing handover performance for UEs, but the algorithm for selecting appropriate HCPs values over 5G system found to be non-robust and non-optimal. Consequently, more efficient HPO algorithm is needed to be developed and validated over 5G system.

In this study, an ADHPO-WF algorithm is developed to adaptively estimate the HCPs values for each UE independently. The ADHPO-WF algorithm estimate HCPs values based on the Weight Function (WF) depending on three bounded functions, which are evaluated as a function of SINR, load and UE speed. Besides that, the weight of each bounded function is taken into account.

The rest of this paper is organized in such a manner. Section II describes the proposed algorithm followed by the system model and the simulation scenario in Section III. In Section IV, the simulation results of the performance obtained by applying the proposed ADHPO-WF algorithm are presented. Finally, Section V concludes the study.

II. ADVANCED DYNAMIC HANDOVER PARAMETER OPTIMIZATION ALGORITHM

An ADHPO-WF algorithm is proposed to dynamically estimate the suitable HCPs values for each UE independently. It considers several influence factors such as, SINR, cell load, and UE's speed. That is to say, the parameters considered to form the functionality of the HCPs should reflect the quality of service, cell conditions, and UE related metrics. This developed ADHPO-WF algorithm adjusts HCPs values based on the variation values estimated by WF. The estimated WF values are mainly depend on three bounded functions, which are evaluated as functions of SINR(γ), Load (L) and UE's speed (v) and their weights. The proposed WF is represented by the following:

$$f_{WF}(\gamma, L, v) = \omega_\gamma \; f(\gamma) + \omega_L \; f(L) + \omega_v \; f(v) \qquad (1)$$

where ω_γ, ω_L and ω_v represent the weights of $f(\gamma)$, $f(L)$ and $f(v)$ respectively. These three bounded functions and the weight of each function are illustrated in the following two sub-subsections respectively.

A. The Bounded Functions

(i). Bounded SINR Function

The bounded SINR function $f(\gamma)$ is a function of the target and serving $SINR(\gamma)$ ratios. It can be expressed by the following formula:

$$f(\gamma) = \left(\frac{\gamma_T}{\gamma_{Max}}\right) - \left(\frac{\gamma_S}{\gamma_{Max}}\right) \qquad (2)$$

where γ_{Max} represents the maximum SINR at the UE (for simplicity, γ_{Max} is set to 30 dB), γ_S and γ_T represent the SINR over the serving and target CCs, respectively.

(ii). Bounded Loads Function

The bounded load function is expressed by $f(L)$, which represents the differences between the target and serving load ratio. The target load ratio is defined as a ratio of the target cell's load to the maximum cell's Load capacity (L_{max}). Similarly, serving load ratio is defined as a ratio of the serving cell's load to the maximum cell's Load capacity(L_{max}). Thereby, the function based on load ratios $f(L)$ can be simplified by the following expression:

$$f(L) = \left(\frac{L_T}{L_{max}}\right) - \left(\frac{L_S}{L_{max}}\right) \qquad (3)$$

where L_T and L_S represent the target and serving cell loads respectively.

(iii). Bounded Speed Function

The bounded speed function is expressed by $f(v)$, which is evaluated as a function of UE's movement speed, v. Thus, the bounded speed function is represented by:

$$f(v) = 2 \cdot log_2\left(1 + \frac{v}{v_{max}}\right) - 1 \qquad (4)$$

where v_{max} represents the maximum expected speed by UE, which is assumed to be constant ($v_{max} = 140$ km/hour) in this study.

B. The Proposed Weight Model

Unfortunately, no mathematical expression has been formulated to estimate the accurate weight of each factor considered in any weight or cost function in the literature [16] [24]. The previous literatures considered different constant weight value for each bounded function. Since the bounded functions adaptively estimate different results based on the performance evaluation, a set of constant value cannot give the accurate weight value for each function. Therefore, there is a need for a mathematical model to estimate the weight value for each bounded function automatically. For that, a mathematical model defined as Automatic Weight Estimator Function (AWEF) is formulated to estimate the weight of each bounded function. This AWEF model is formulated by the following:

$$\omega_n = \frac{1 - f(x_n)}{\sum_{i=1}^{F}(1 - f(x_i))} \qquad (5)$$

where ω_n represents the weight of function n, which can be a function of γ, L or v, $f(x_n)$ is the corresponding function

n that needs to evaluate its weight F is a metric's factor, which represents the total numbers of parameters that are considered for adapting HCPs values. In this study, F is set to 3 since there are three factors considered $(\gamma, L$ and $v)$, $f(x_i)$ is the function of x that corresponding to i, whereas i is varied from 1 to F. For simplicity, $f(x_1)$ can be $f\ (\gamma)$, while $f(x_2)$ can be $f\ (L)$ and $f(x_3)$ can be $f\ (v)$. Thus, this function (Eq. 5) can estimate the weight of each bounded function.

Accordingly, the HCPs values can be estimated based on the AWEF as illustrated in the following two sub-sections:

C. Handover Margin Level

Based on the formulated WF, change in the HOM level (ΔM) can be determined by the following formulated expression:

$$\Delta M = \begin{cases} \mathcal{M}\, f_{WPF}(\gamma, L, v) & if \gamma_{T,S} \leq \gamma_{Thr} \\ \mathcal{M}\left(1 + \omega_L\, f(L) + \omega_v\, f(v)\right) & if \begin{matrix} \gamma_T < \gamma_{Thr} \\ \gamma_S \geq \gamma_{Thr} \end{matrix} \\ \mathcal{M}\left(-1 + \omega_L\, f(L) + \omega_v\, f(v)\right) & if \begin{matrix} \gamma_S < \gamma_{Thr} \\ \gamma_T \geq \gamma_{Thr} \end{matrix} \end{cases} \tag{6}$$

where, $\mathcal{M}$ represents the average handover margin level, which is evaluated as:

$$\mathcal{M} = (M_{max} - M_{min})/2 \tag{7}$$

Thus, the HOM level can be adaptively estimated using the following expression:

$$HOM = \mathcal{M} + \Delta M \tag{8}$$

D. TTT Intervals

The ADHPO-WF algorithm is adaptively selecting the suitable TTT interval based on the variation of WF. The range of TTT intervals has been specified by the 3rd Generation Partnership Project (3GPP) in [25] Section 6.3.5. The specified TTT (T) intervals vary from 0.00 to 5.120 second. Accordingly, the adaptive TTT intervals can be determined by the following mathematical expression:

$$\Delta T = \begin{cases} Z1 & if\ \ T_{min} < T < T_{max} \\ Z2 & if\ \ T = T_{min} \\ Z3 & if\ \ T = T_{max} \end{cases} \tag{9}$$

where, $Z1$, $Z2$ and $Z3$are represented by Eq. (10), (11) and (12) respectively.

$$Z1 = \begin{cases} T - \rho & if f_{WPF} \leq f_{WPF} + Q \\ T + \rho & if f_{WPF} \geq f_{WPF} + Q \end{cases} \tag{10}$$

$$Z2 = \begin{cases} T & if f_{WPF} \leq f_{WPF} + Q \\ T + \rho & if f_{WPF} \geq f_{WPF} + Q \end{cases} \tag{11}$$

and

$$Z3 = \begin{cases} T - \rho & if f_{WPF} \leq f_{WPF} + Q \\ T & if f_{WPF} \geq f_{WPF} + Q \end{cases} \tag{12}$$

where Q and ρ represents the optimization step level and interval, respectively.

The constants, ρ and Q, are meant to adjust the resolution, in which the TTT intervals are updated. If these constants are selected to be small, higher resolution of TTT is achieved. However, too high the TTT resolution may impose high computational complexity and delays to the system. Thus, for simplicity, the values of ρ and Q are selected to be 0.04 s and 0.1 throughout the simulation. Furthermore, it can be noticed that, when the update value is saturated at T_{max} or T_{min}, then no further update is considered. The T_{max} or T_{min} are determined from the 3GPP recommendations as 0.0s and 5.12s respectively.

The initial values of HOM and TTT for all the implemented HPO algorithms are assumed to be 2 dB and 100 milliseconds respectively.

III. SYSTEM AND SIMULATION MODELS

The ADHPO-WF algorithm is validated in 5G system, which is modeled according to 3GPP specifications for 5G LTE-Advanced Pro [24]. The system is deployed by considering 61 macro hexagonal cell layout model. Each hexagonal cell is built with an inter-site distance of cell radius in meter, with one eNB located at its center. Each hexagonal cell consists of three sectors' antenna. As for frequency planning, a unity Frequency Reuse Factor (FRF) is assumed for all cells.

The simulation implements the developed ADHPO-WF algorithm to validate its performance in the system. The performance results, in this simulation, are analyzed in contrast to the performance of various HPO algorithms for different UE speeds. Initially, the essential 5G parameters defined in 3GPP specifications Release 16 are considered in this simulation as listed in Table 1. The traffic rate in this simulation is generated randomly to reflect the change of UE demands in the network.

The UEs are assigned five different speeds through the simulation as they are stated in Table 1. During the simulation also, the UE direction and position are updated randomly and their Euclidian distances from the eNB in the network are calculated in a distance matrix. From this distance matrix, the path losses experienced on the signal are estimated in addition to the log-normal shadowing, and Rayleigh fading in multipath scenarios. The Reference Signal Received Power (RSRP) and SINR perceived by each UE is, then, estimated from each carrier received signals. Each eNB in the network updates the RLF and ping-pong report during the simulation. Moreover, the eNB updates the load report and transmit its load information to the other eNB in the network. From the UE perspective, the average SINR and RSRP over the carrier is measured by each UE and then transmitted to the respective eNB for the optimization process. The eNB performs the

Modulation and Coding Scheme (MCS) selection according to the received SINR and RSRP reports and then, executes the self-optimization process.

Upon the completion of the self-optimization process, the serving eNB will perform the handover decision according to the Measurement Report (MR) and HCPs estimated by executing the handover procedure sequence in 3GPP [26, 27]. Otherwise, as the serving eNB provides satisfactory signal quality, the connection with UE will be maintained.

TABLE I. SIMULATION PARAMETERS [24, 26-28]

Parameter	**Assumption**
Environment	Micro cells, Urban areas, 5G Release 16 System
Cellular Layout	Hexagonal grid, 61 cell sites, 3 Sectors
Interference Model	Co-Channel Interference (CCI) from six neighboring eNBs in the first tier
Path Loss Model	$L = 79.2 + 26\ x\ log_{10}(d)$
Shadow Fading Model	Gaussian-distributed random variable with zero mean and σ_{dB} standard deviation in dB
Fast Fading Model	Rayleigh fading model
eNBs antenna height	15 m
Cell radius(d)	200m
Carrier frequency	28 GHz
Total eNB TX Power	46 dBm
Shadowing (σ)	8 dB
White Noise Power Density (Nt)	-174 dBm/Hz.
eNBs Noise Figure	5 dB
Thermal Noise Power (Np)	Np = Nt + 10 log (BW x106) dB
Number of tested UEs	200 distributed randomly
UE Noise Figure	9 dB
UE height	1.5 m
UE's Antenna Gain	0 dB
UE's Antenna	1 (Omni-directional)
Mobility Model	Random Mobility Model (RMM)
UE's speeds	Ranging from 40 to 140 km/hour in steps of 20 km/hour
Resource Distribution	evenly over all the active UEs
System Bandwidth (BW)	500 MHz
Cyclic Prefix length	Normal
Number of PRBs	2500 PRBs
Modulation Scheme	AMC scheme
Resource Distribution	evenly over all the active UEs
HO Decision Algorithm	$RSRP_S > RSRP_T + HOM$
Q_rxlevmin	-101.5 dBm
Handover Margin	Adaptive
TTT	Adaptive (0 ms to 5120 ms)
T311 interval	10 s

The radio link connection condition is monitored and updated in the serving eNB regularly. In the case of RLF detection, the Radio Resource Control (RRC) re-establishment procedure is initiated. In this procedure, the UE scans the received signals from all the neighboring cells, and then selects the target cell that can fulfill the minimum required signal level. The cell that provides the strongest signal quality, if multiple cells satisfy the criteria, would be selected by the UE. Upon the selection of the cell by the UE, the RRC re-establishment procedure is initiated to configure the connection within T311 interval. Conversely, if none of the cells satisfy the minimum requirements, the Non-access stratum (NAS) recovery procedure is enabled. The UE continues to identify a suitable cell in the target eNB throughout the NAS recovery procedure. The search is repeated until a suitable cell is identified and reconnection takes place. Finally, the system performance is evaluated at the end of each simulation cycle.

IV. RESULTS AND DISCUSSION

The proposed ADHPO-WF algorithm is validated and assessed over the 5G 3GPP Release 16 system. The simulation results are presented and discussed in different mobile speed conditions. Moreover, the results of the ADHPO-WF algorithm are compared to the conventional HPO [1, 2, 5, 7, 29], WPHPO [16] and FLC [14] algorithms. The WPHPO and FLC algorithms are chosen from the literatures, because they are mostly focused on developing the HPO function among the latest works. Accordingly, the presented results illustrate the effect of the developed ADHPO-WF algorithm on the handover probability, handover ping-pong effect and RLF.

The average HOP versus mobile speed for the ADHPO-WF algorithm is presented in Fig.1. The results carry out that, the proposed ADHPO-WF algorithm provides a significant reduction gain as compared to the other algorithms. From the observation in Fig.1, the ADHPO-WF algorithm achieves the same reduction gains with all the considered mobile speeds. That may due to the consideration of UE's speed through the optimization process. Accordingly, the average reduction gains achieved by ADHPO-WF algorithm are around 93, 97 and 88.8% lower than the conventional HPO, FLC and WPHPO algorithms, respectively.

Similarly, the ADHPO-WF algorithm produces a significant reduction gain in terms of HPPP as compared to the other algorithms, as illustrated in Fig.2 and 3. This HPPP may occur when suboptimal HCPs values are estimated. That may lead to increase the unnecessary handover probability (HPPP), especially during high speed. This in turn may increase the waste of network resources. Therefore, HPPP should be reduced as much as possible to preserve network resources. The presented results in Fig. 2 illustrate the average HPPP with three different mobile speeds. Whereas, the results in Fig. 3 represent the total average HPPP overall mobile speeds. These results carry out that, the proposed ADHPO-WF algorithm provides lower HPPP under the considered mobile speeds. That illustrates the robustness of the proposed ADHPO-WF algorithm under the low, medium and high mobile speed. The total average achievable reduction gains by ADHPO-WF algorithm are around 99.4, 98.9 and 99.8% lower than the conventional HPO, FLC and WPHPO algorithms, respectively.

Beside the enhancements of HOP and HPPP, the estimated HCPs values by ADHPO-WF algorithm is also contributed to reduction in the RLF probability. The RLF is usually resulted as an outcome of estimating suboptimal HCPs values that may cause a too late handover", "too early handover or handover to a wrong cell, which lead to increase RLF probability, particularly during the high mobility speed scenarios. Frequent occurrence of RLF leads to unstable connection. The RLF reduction is noticeably illustrated in Fig. 4. The results point out that, the proposed ADHPO-WF algorithm performs higher RLF reduction gains than all the other algorithms with different mobile speed scenarios. It achieves as average reduction gains around 20, 65 and 29.6% lower than the conventional HPO, FLC and WPHPO algorithms, respectively. Thus, the proposed ADHPO-WF algorithm provides the best reduction gains as compared to the other algorithms. This reduction gains attributes to the robustness of the ADHPO-WF algorithm for estimating the suitable HCPs values.

The presented results illustrate that, the proposed ADHPO-WF algorithm provides the best performance evaluation as compared to the conventional HPO, FLC and WPHPO algorithms. As it achieves an average reductions gain around 93, 99 and 38.2% less than all the literature algorithms in terms of HOP, HPPP and RLF respectively. These reduction gains lead to significant reductions in the RLF with different mobile speed scenarios as well. These reductions reinforce system performance in terms of increasing connection continuity and reliability, especially through the high mobility speeds. The reduction of the RLF ensures maintaining the radio link connection between the served UE and serving network. This leads to seamless connection and provides a reliable connection through the mobility of UEs within the cells. These results indicate that, the ADHPO-WF is the best HPO algorithm that enhances handover performance with different mobile speed scenarios compare to the investigated HPO algorithms in this study.

These enhancement gains are attributed to the influences of the three considered factors (SINR, UE's speed, cell load) and the individual estimation for each UE independently. In other words, the ADHPO-WF algorithm performs the optimization for each UE independently based on UE's SINR, UE's speed and cells loads. This led to estimate the suitable HCPs values for each UE independently without affecting the other UEs in the cell. That allowed the UE to connect to the best cell continuity without any retraction from the serving network, which mean that, the proposed ADHPO-WF algorithm discharges the central control in the optimization process. On the other hand, the other algorithms from previous works perform the optimization process centrally by the eNB. This central control gives restriction to the UEs, where this adjustment can be useful for some UEs, but at the same time at affect the other UEs. Consequently, the proposed ADHPO-WF algorithm is more robust than the existing algorithms in the literature. Thus, it can be stated that the ADHPO-WF can be considered as one of the robustness HPO algorithms in 5G systems.

V. CONCLUSION

In this study, a new ADHPO-WF algorithm was proposed to dynamically estimate the HCPs values based on a WF. This WF estimated the optimization values based on UE's SINR level, cells' load and UE's speed. Furthermore, the proposed ADHPO-WF algorithm gave the serving network freedom for adjusting the HCPs values for each UE independently. Thus, each UE got a different HCPs setting than the other UEs. These HCPs optimization values were validated over 5G system over various mobile speeds. The performance is assessed in terms of HOP, HPPP and RLF. The simulation results have shown that the proposed ADHPO-WF algorithm achieved significant reduction gains, compared to the HPO-Cnv, FLC and WPHPO algorithms. Consequently, ADHPO-WF algorithm can be considered as one of the significant HPO algorithms in 5G systems.

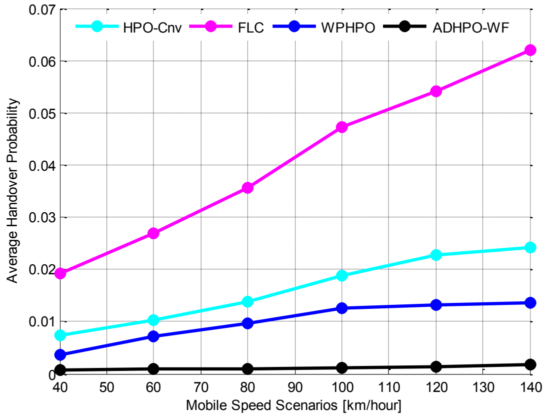
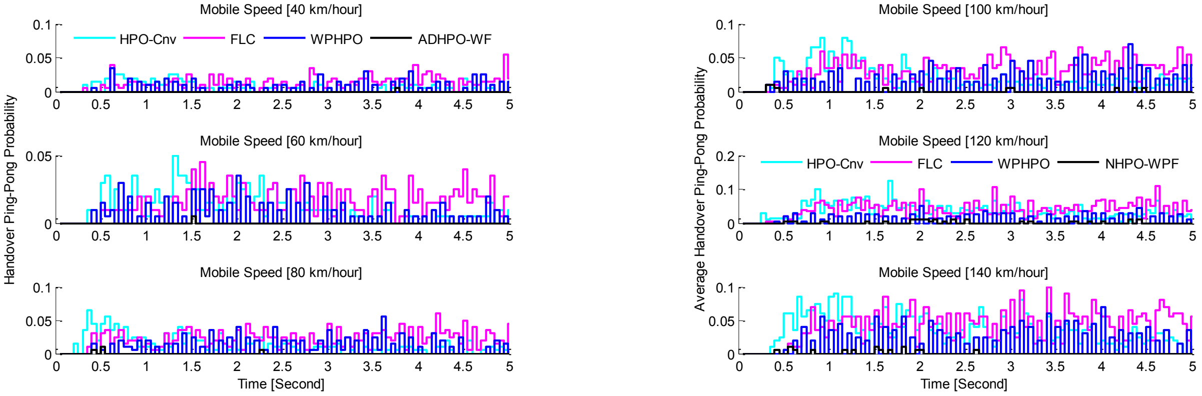


Fig. 1. Handover probability versus mobile speed



(a)

(b)

Fig. 2. HPPP with different mobile speeds

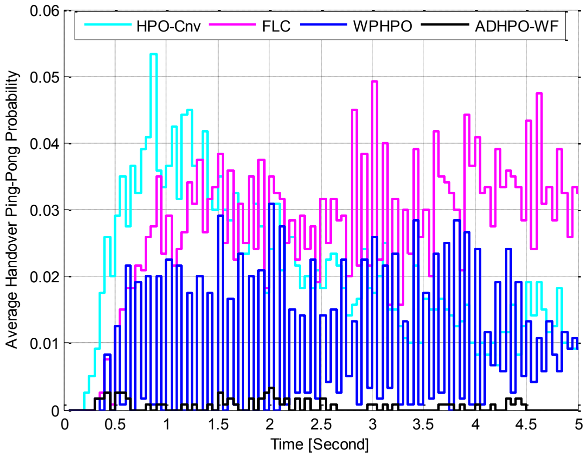


Fig. 3. HPPP overall mobile speed scenarios versus time

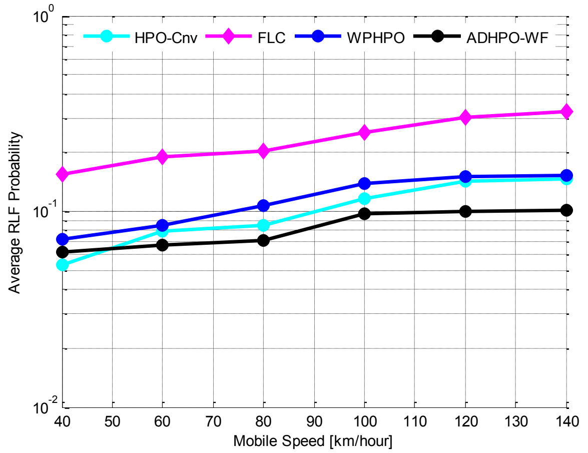


Fig. 4. Average RLF probability versus mobile speed

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